APPLE VHF ANTENNA SYSTEM

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This paper details the VHF antenna system used in APPLE spacecraft for telemetry, tracking and command operations. Also is included the in-orbit performance and measurement of the system during the pitch rotation of the spacecraft.

Indexing terms : Spacecraft antennas, Omnidirectional antenna, Turnstile array

APPLE the first Indian Experimental Communication Satellite was launched by the third developmental flight of ARIANE (ESA Launcher L03) in July 1981. It is a three-axis body stabilized, geostationary spacecraft designed for a life time of two years, which it completed successfully after achieving all the goals set for the mission. The satellite telemetry and tracking used VHF link during transfer orbit phase, C-band link during on-orbit phase, while the command operation was always through VHF. A back-up mode for on-orbit ranging was also provided which used VHF uplink and C-band downlink. Thus a very reliable VHF link was desired throughout the life time of the spacecraft. This paper deals with the details of design and development of the VHF antenna system used for the mission.

DESIGN AND DEVELOPMENT

Apart from the mission requirement of omnidirectional coverage during the transfer-orbit phase, there were a number of severe constraints posed from the spacecraft side like non-availability of space on the top, bottom or on any part of the main body of the spacecraft to mount the antennas, restriction of antennas within the dynamic envelope of the heat shield etc. Keeping all the constraints in view, various schemes were considered [1, 2, 3, 4, 5, 6] and finally, a turnstile system of four monopoles fed in phase quadrature was chosen as the best candidate for this mission. The antennas were mounted on the solar panel back-up flanges which were rivetted to the main body of the spacecraft. As this was the only available space for mounting the antennas, the optimization of the system was greatly restricted. After a series of experimentation for various monopole lengths, bending angle, mounting configuration etc, the final system arrived at, had the specifications as indicated in Table 1. The feeding network (Fig 1) was designed to give a progressive phase difference of 90° at telemetry frequency to have a better margin for downlink.

EXPERIMENTAL RESULTS AND DISCUSSIONS

All the parameters of the antenna system were evaluated from the radiation pattern measurements [7, 8] conducted

TABLE 1. Specifications of VHF antenna system

Electrical	
Type	Turnstile array of four monopoles fed in phase quadrature
Frequency range	136—150 MHz
Pattern	Omni directional
Minimum gain	—12 dB (with respect to isotropic level)
VSWR	1.5
Connector	TNC (F)
Mechanical	
Length of each monopole	70 mm (0.33 λ, f=143 MHz) straight length+450 mm (0.215 λ) bent length
Mounting	135° to spin axis
Material	Al-2024, brass (gold plated) S.S. (gold plated) teflon
Weight	1.4 kg including feeding network

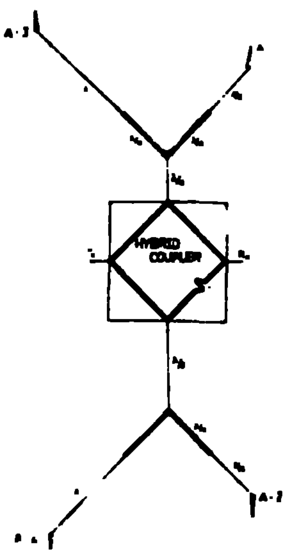

Fig 1 VHF antenna feed system

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on a 0.4 size scaled model of the spacecraft. The spacecraft was also wrapped with multilayered insulation blanket to simulate the actual configuration. The measurements were carried out in an outdoor range with satellite at the receive end and a dual polarized crossed yagi at the transit end. The radiated levels for both dual linear and circular polarizations were obtained at transmit and receive ports and at their respective frequencies of 137.292 and 149.522 MHz. Enormous amount of data collected were used to prepare radiation-gain contour plots for different polarizations, frequencies, and transmit/receive ports. Two such sample plots are shown in figures 2&3. These contour plots act as ready reference to know the radiation intensity levels for any orientation of the spacecraft.

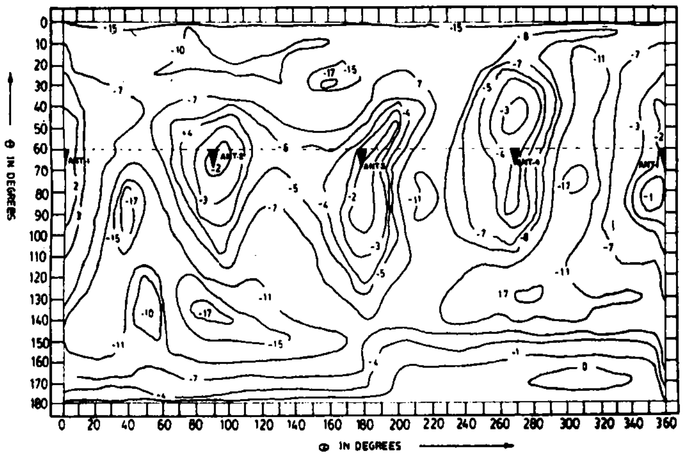

Fig 2 APPLE VHF antenna pattern telecommand (LHC)

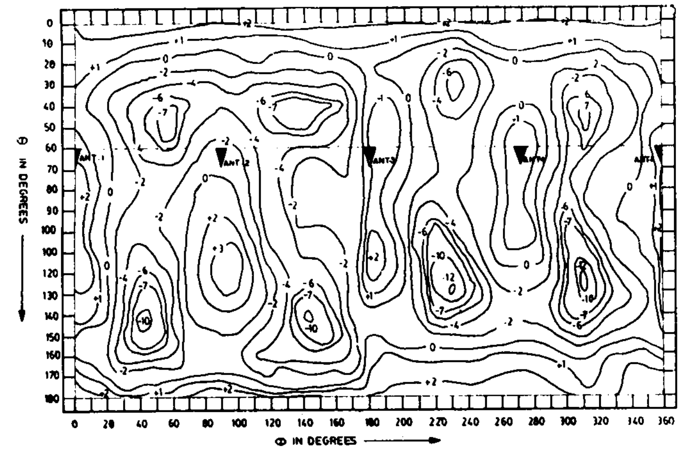

Fig 3 APPLE VHF antenna pattern telemetry (RHC+LHC)

Measurements were conducted exhaustively for stowed condition of the solar panel to simulate the transfer-orbit phase and to a limited extent for deployed case of the solar panel. The results indicate worst dips of the order of —15 dB for single polarization and —12 dB for matched polarization. Summary of the test results are given in Table 2. Hence, to ensure uninterrupted link :

(*i*) a diversity combined receiver for telemetry reception

and (*ii*) a switchable orthogonal circular polarization facility for command operations,

are essential at the ground station.

TABLE 2. Summary of test results

(A) COVERAGE

(*i*) *For Matched Polarization*	(*ii*) *For Single Polarization*
80% area > —4 dBi	50% area > —6 dBi
99% area > —8 dBi	60% area > —7 dBi
100% area > —12 dBi	75% area > —10 dBi

(B) OTHER RESULTS

Parameters	Stowed solar panel		Deployed solar panel	
	Tx port	Rx port	Tx port	Rx port
Return Loss (dB)	18	25	16	28
Isolation (dB) between Tx & Rx Ports at				
(*i*) 137.292 MHz	10		10	
(*ii*) 149.522 MHz	18		9	

As regards impedance measurements, it was carried out on a full-scale flight model of the spacecraft. Free-space conditions were realized in the open field using RF absorbers on ground and the spacecraft was fixed on an open bullock cart platform (Fig 4) for easy transportation as well as to act as a non-reflective platform during the tests. The measurements were made using HP 8410 Network Analyzer System. The results are indicated in Table 2 and were within acceptable limits.

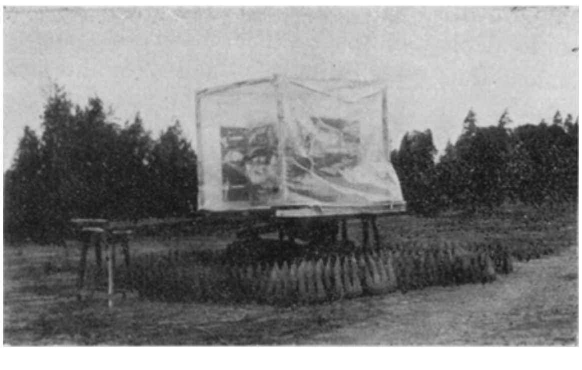

Fig 4 APPLE spacecraft mounted on bullock cart for impedance measurements

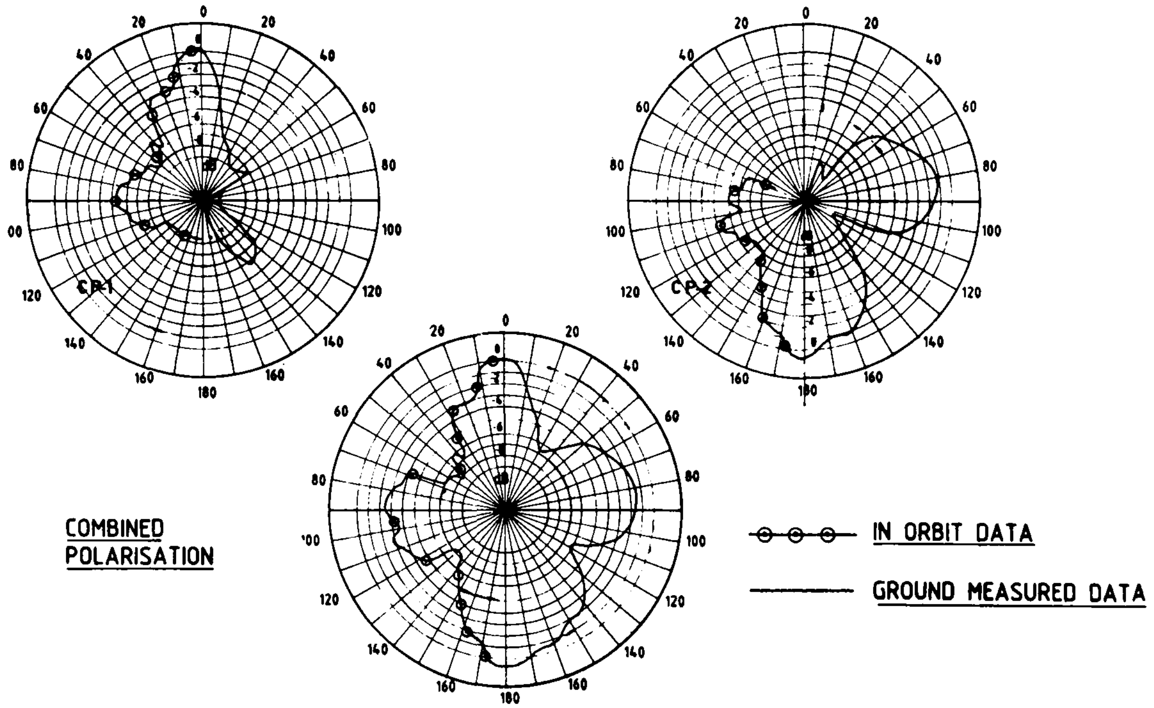

Fig 5 In-orbit antenna pattern measurements on APPLE VHF antenna system

ENVIRONMENTAL TESTS

The antenna system was subjected to various conditions of temperature, pressure, vibration and shock levels which it would undergo during launch and in orbit. The system went through all the tests successfully.

IN-ORBIT PERFORMANCE

After launch of the spacecraft, various systems on-board were tested for their performance in space. The antenna systems were evaluated during the pitch rotation carried out for reducing the thermal influx on the horizon sensor owing to over heating of the sun caused due to non-deployment of one solar panel. The results obtained are given in Fig 5. The measurements made on the ground with stowed solar panels are also included in the figure for immediate comparison. The in-orbit results are with single panel deployed as the other panel failed to deploy in space. The two results show good agreement thus establishing the validity of the measured patterns.

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REFERENCES

1. S.Pal, P.K. Reddy, V.K. Lakshmeesha, *et al.*, On-board antenna systems for Bhaskara missions, *Journal of IETE*, vol 29, pp 154-159, April 1984.
2. S. Pal & M.K. Saha, Suitability of turnstile and helical antennas for space applications *Journal of Indian Rocket*, vol 1, pp 150-161, April 1971.
3. G.H. Brown & O.M. Woodward, Circularly-polarized omni-directional antenna, *RCA Review*, vol 8, pp 251-269, 1947.
4. C. Ancona & E. Do-Boi, The Symphonie satellite VHF circularly polarized antenna with toroidal patterns, IEE Conference Publication No. 128, pp 148-152, 1975.
5. On-board VHF & UHF Antenna systems for SEO (Satellite for Earth Observation) ISAC Document No. SEO-ISAC-11-77-05-019, May 1977.
6. S.P. Kosta, S. Pal, P.K. Reddy, V.K. Lakshmeesha *et al.*, Antenna systems for the Aryabhata mission, vol 1, pp 221-234, Sept 1978.
7. W.H. Kummer & E.S. Gillespie, Antenna Measurements—1978, vol 66, pp 483-507, April 1978.
8. J.S. Hollis, T.J. Lyon & L Clayton, Microwave antenna measurements, Scientific Atlanta Inc. Georgia, 1970.
9. B. Pugh, Antennas in space environment, IEE conference publication No. 128, pp 21-28, 1975.